

CONDITIONED REFLEXES AND HABIT FORMATION

BY

W. HORSLEY GANTT, B.Sc., M.D.

(Phipps Psychiatric Clinic, Johns Hopkins Hospital, Baltimore)

Habits are but chains of conditioned reflexes. Pavlov says: "It is obvious that the different kinds of habits based on training, education, and discipline are nothing more than a long chain of conditioned reflexes." Even as far back as 1890, William James recognized the reflex character of habit, "that, of course, a simple habit, like every other nervous event—the habit of snuffling, for example, or of putting one's hands into one's pockets, or of biting one's nails—is mechanically nothing but a reflex discharge, and its anatomical substratum must be a path in the nervous system." In habit we have a situation, a response, and a reward, which may be either distant or immediate. In the conditioned reflex terminology there is a signal or conditioned stimulus (situation) and the conditioned reflex, and usually immediately (in our experimental room) there follows the unconditioned stimulus plus unconditioned reflex.

DEFINITION OF CONDITIONED REFLEX

The conditioned reflex is formed during the life of the animal, is subject to fluctuation, and is a peculiarity of the individual rather than of the species. It is much less stable than the unconditioned reflex. Some of the very old and well-formed conditioned reflexes are difficult to distinguish from those unconditioned. For example, is the winking of the eye when an object is brought suddenly in front of it a conditioned or an unconditioned reflex? It is present in practically every one of us, and is relatively stable and unchanging. Is the secretion of saliva in a dog to the odour and sight of fresh meat that is presented to it conditioned or unconditioned? Volborth has shown that in newborn calves there is no winking until the object has impinged upon the eye, but once this has happened there is ever after the winking reflex. Puppies that have never eaten fresh meat do not salivate when it is presented to them for the first time, but once they have had it in their mouths and the odour and

sight are associated with the unconditioned flow produced by the presence of the meat in the mouth, chewing, etc., the odour and sight become conditioned stimuli or signals for the unconditioned stimulus (meat in the mouth), and they call out an unconditioned reflex. On the other hand there are certain pungent odours, such as that of ammonia, which from the beginning produce unconditioned buccal and nasal secretions.

ESSENTIALS OF CONDITIONED REFLEXES

Let us see in what circumstances the conditioned reflexes or simple habit patterns are formed. First, there must be some "emotional" disturbance (I employ "emotion" here in the rather broad sense of a fundamental subcortical excitation, as used by the Pavlov school), an excitation in the centre to which we desire to elaborate the conditioned reflex. The more intense the emotion the stronger will be the resulting conditioned reflex, and the quicker its elaboration. This emotion, however, must be in that centre with which we are working and not in another. For example, if we are using the food reflex the dog must be hungry; if the defence centre, the unconditioned stimulus of pain—or, as Pavlov says, destructive stimulus—must be strong enough to produce the necessary excitation in that centre: an electric current that is too weak will not suffice.

Then our conditioned reflex must be formed on the basis of some unconditioned reflex with which the animal is supplied; we must take into account the kind of unconditioned reflexes with which our experimental organism is stocked. These naturally are different for different species, for man and dog. In the latter we generally employ the food reflex because it is the salivary component which is easily measured. We sometimes use the defence reflex; but the muscular movements are not nearly so adaptable for our purpose, as they are difficult to measure quantitatively. Other reflexes of which we may avail ourselves are the investigating or orienting reflex—the turning of the animal to any new stimulus—and this is present in a wide range of organisms. The task of studying and classifying the unconditioned reflexes is yet to be performed.

Next, we must have an indifferent signal as our conditioned stimulus—one that does not of itself evoke any marked emotional state. This is in general true, although it is possible to convert a strong current into a stimulus for food, so that even when the skin is burned the dog shows the food reaction but not the pain reaction, the

food centre being of more physiologic importance to the animal than the destructive pain stimulus. No agent is really indifferent, because even though it may not naturally call forth any reaction, and though it may be new for the dog and have no performed connexions, it always provokes the orienting or investigating reflex. Then the conditioned stimulus must precede the unconditioned. This was thought to be essential until recently, when Pavlov showed that the conditioned stimulus following the unconditioned may eventually acquire a slight conditioned value. However, this may cause a hypnotic state in the animal.

FORMATION OF CONDITIONED REFLEX

What is the mechanism of the formation of the conditioned reflex? Not simply the repetition alone. Pavlov explains it by saying that the excited food centre draws all simultaneous stimuli to itself, and so a path is made in the cortex between all changes in the *milieu* and the excited centre. Then the organism must be in the proper state ; for example, we cannot form a conditioned food reflex if the animal has just satiated itself.

Now we come to the formation of the conditioned reflexes. The conditioned stimulus—that is, any change in the internal or external *milieu* of the dog—must be repeated one or more times with the unconditioned stimulus. The number of repetitions varies with the species, the intelligence, age, etc. In fish it may be necessary to repeat the laboratory stimulus three hundred times to form the conditioned reflex, for the dog ten to fifty times, and in a child four to ten times. Old animals elaborate conditioned reflexes very slowly or not at all. An idiot may not form the conditioned reflex as quickly as a fish. These cortical reflexes about which we are speaking are continually coming into existence, fluctuating in intensity, diminishing, increasing, and disappearing—that is, they are conditional. This brings us to the question of inhibition.

INDIRECT INHIBITION

The conditioned reflex may be subject to two kinds of inhibition. One sort is that described by Sherrington, and is analogous to spinal inhibition. It occurs when two centres are in activity at the same time ; a conflict arises for the dominance of the field. As the activity is in a different centre from the one with which we are working, Pavlov calls it *external or indirect inhibition*. Examples are occurring every minute of our lives. We have given

the conditioned food stimulus and the dog turns toward the place where the food is ; if we enter the room our presence there inhibits the food reflex, and he turns away from the food toward the newcomer. Or the rumble of a passing truck, the sight through the window of a moving body, may do the same thing. Internal conditions act similarly. For example, the tension of a full bladder or some irritating lesion in the mouth or on the body of the animal may diminish or inhibit all the conditioned food reflexes till this factor is removed.

DIRECT INHIBITION

The other type of inhibition is a distinctive cortical phenomenon. It has entirely different properties from the external inhibition. First, it develops as a gradual process and does not reach a maximum until some lapse of time, perhaps hours, days, or weeks, while external inhibition has its full effect the first time it is used. The second kind of inhibition has the property of becoming diffuse, spreading over the cortex, remaining a long time, and then concentrating again. It does not arise in a separate centre ("centre" being employed in a functional sense), but it is in the same receptory region with which we are concerned—where the excitation is. It is closely connected with the process of excitation from which it arises. This is the *internal, direct, or cortical inhibition*.

The simplest way in which it is brought about is by *extinction* of the conditioned reflex—that is, by repetition of the conditioned stimulus and failure to support it by the unconditioned stimulus (giving food in the case of the food reflex). When the conditioned stimulus is thus applied a certain number of times without reinforcement the flow of saliva gradually decreases with each repetition, and finally drops to zero. Just as with elaboration of conditioned reflexes so with extinction, the number of repetitions varies with the animal, age, and intelligence. Children are much more plastic than dogs, in that conditioned reflexes are elaborated quicker and disappear faster when they are not reinforced—the salivary, for example, after five to ten trials as compared with ten to sixty for the dog. The conditioned reflex thus extinguished after a lapse of a certain time undergoes *restoration*. In two dogs in which Dr. Wolff and I extinguished three reflexes completely by August 1st, 1930, when they were tried on October 1st, 1930, the salivary secretion was as active as before the extinction, though no work had been done on the animals in the interim. When the first conditioned reflex has been ex-

tinguished others are extinguished after a fewer number of trials, and it is so even with those for other receptors. Then, when the conditioned reflexes are restored, extinction is much easier than it was the first time.

ASSOCIATIVE INHIBITION

The second kind of internal inhibition is associative or conditioned inhibition, which occurs when the indifferent agent is given together with the positive conditioned stimulus and the combination is reinforced. Suppose we have a metronome (M) which we have made into a positive conditioned stimulus. Every time we use it we give food. Now we give the metronome plus the light (L) (which has never been used before) ; with this combination we do not give food, although each time we give M alone we do feed the animal. At first the animal reacts to the combination of M and L as it does to M alone, but as this stimulus is repeated the salivary secretion to it gradually diminishes to zero, although M alone gives the same effect as before. L, which was indifferent for the food centre, has now acquired an inhibitory value, not only for the stimulus with which it was used, but for other food stimuli and also for stimuli of other centres. For example, if we now combine L with a bell (B), which is a positive food stimulus, the combination L plus B produces no salivary flow the first time it is used. L, from its association with M, now has a different significance for the animal from what it had before it was used with M. Or even if L is given with a conditioned stimulus—not for food but for the introduction of acid into the mouth—it will inhibit the conditioned reflex to the acid. Thus we come to see that all extraneous and accidental stimuli or changes in the environment coinciding with an inhibitory state of the animal in time acquire the property of themselves calling out this inhibition.

CHAIN CONDITIONED REFLEXES

How closely related internal inhibition and excitation and how slight a change in temporal relations constitute the determining factor as to whether the same indifferent agent under otherwise identical conditions becomes positive or negative—"a hair perhaps divides the false from the true," as the poet has it—are seen in this example. If we combine the positive conditioned stimulus M with some agent L so that M coincides with it and overlaps it, then L becomes an inhibitory signal—a conditioned inhibition. But if L precedes M by a few seconds, then L takes on the character of a positive conditioned

stimulus, although M here is not accompanied by food. In this way *chain conditioned reflexes* are established. L becomes a signal for M ; this has already been made a signal for food, so L eventually calls out the same food reaction, though a weaker one than M. Conditioned reflexes are thus four-dimensional.

DIFFERENTIATION

Say we elaborated a positive conditioned reflex with a metronome of 100 beats per minute (M 100). Let us try one of 200 beats and not accompany it with food. The first time M 200 is used the dog reacts to it as he did to M 100, and only when it is repeated a number of times without food does it become inhibitory—that is, does the flow of saliva cease. Pavlov has performed experiments which show that the process of excitation set up by M 100 spreads over a certain area of the cortex and contracts only after M 200 has been presented. If we bring the positive and negative conditioned stimuli close enough together—for example, by using M 110 instead of M 200—we might produce a neurosis by a “collision” of the processes of excitation and inhibition.

WILLIAM JAMES ON HABIT FORMATION

What are the implications of the teaching of conditioned reflexes for habit formation? What support do they give to the rules for habit training formulated by William James? First he says:

“ We must make automatic and habitual, as early as possible, as many useful acts as we can.”

That is, we must elaborate conditioned reflexes to the proper stimuli or situations (complex stimuli), and as early as possible, because young animals form them more easily than older, and the first reflexes are the strongest. Secondly:

“ Launch ourselves on as strong and decided an initiative as possible. Accumulate all the possible circumstances which will reinforce the right motives ; envelop your resolution with every aid you know.”

Here we have the bringing of emotion into play, and we know that a certain emotional tension is necessary for the elaboration of conditioned reflexes ; a dog which is not hungry will not form a conditioned food reflex. Thirdly:

“ Never suffer an exception to occur until the new habit is securely rooted in your life. Each lapse is like the letting fall of a ball of string which one is carefully winding up ; a single slip undoes more than a great many turns will wind up again.”

We have just seen how extinction of the conditioned reflex may easily occur when the conditioned stimulus is given too often without supporting it by the unconditioned. In the habits of adults the unconditioned stimulus is perhaps far removed from the conditioned stimulus, and is linked up to it through a long chain. The alarm clock rings ; we do not get up, and it ceases to stimulate us, to call out the conditioned reflex of arising. The unconditioned stimulus here is not so easy to detect as in the dog which fails to react to the bell connected with food, and it is probably a compound one (the fear of falling into disrepute, losing of one's job, meeting with disapproval—which is quite likely an unconditioned stimulus for man just as an overpowering frightful enemy is for an animal).

Again :

“ Seize the very first opportunity to act on every resolution you make, and on every emotional prompting you may experience, in the direction of the habits you aspire to gain. It is not in the moment of their forming, but in the moment of their producing motor effects [that is, conditioned reflexes], when resolves and aspirations communicate the new set to the brain. . . . No matter how full a reservoir of maxims one may possess, and no matter how good one's sentiments may be, if one has not taken advantage of every concrete opportunity to act, one's character may remain entirely unaffected for the better.”

This is just the same way of stating the preceding rule from the standpoint of conditioned reflex elaboration. James's final rule of “ keeping the faculty of effort alive in you by a little gratuitous exercise every day ” involves both the emotional state and the value of repetition in the elaboration of conditioned reflexes and in the prevention of their gradual spontaneous extinction.

MORALS AND PREJUDICES

Besides these maxims we wish to make several direct applications from the study of conditioned reflexes to habit formation. It will be seen that after the first conditioned reflex in a certain centre is elaborated it takes fewer trials for each succeeding one up to a certain point. This is a basic law of education. That extinction of the second conditioned reflex is much easier than of the first, and that when once it has been extinguished and restored it is never so stable as it was before extinction, has an enormous significance in the destruction of moral codes, explaining why a person untrustworthy in one thing is usually so in another, the chaos produced by revolutions

and wars, the difficulty of bringing about permanent cures in drunkards, culprits, etc.

How strong the old conditioned reflexes are and their spontaneous restoration after extinction, and how quickly recently elaborated conditioned reflexes disappear, is seen in the readiness with which habits cultivated late in life are abandoned, and in how inevitably and easily a man who has acquired new manners and culture removed from his early surroundings lapses back into his former habits, ungrammatical slips of the tongue, accent, etc. (though they may not have been used for years), when he returns to the old situation. The fact that a delayed reflex is weaker than an immediate one explains the demoralizing effect of the action of procrastination, and the nervous tension (conflict between excitation and inhibition) when rewards (unconditioned stimuli) are too long withheld in those unaccustomed to maintaining a balance between the processes of excitation and inhibition. And cannot many of our prejudices find an explanation in the phenomena of conditioned inhibition? Here all accidental stimuli or changes in the environment which may be entirely without significance for the organism will, if they coincide with an inhibitory state in the animal, after a certain number of coincidences of times provoke the same state when they occur alone.

DANGER OF REPEATED STIMULI

Perhaps we might learn something from the laboratory concerning the repetition of conditioned reflexes. Too frequent use of the same conditioned stimulus may become injurious. Instead of leading to the successful elaboration and establishment of the desired conditioned reflex (habit), its weakening and disappearance may ensue—that is, it may pass over into an inhibitory agent despite reinforcement each time. This is especially true of certain kinds of weak stimuli (tactile and thermal for the dog). Between such failing stimuli it is necessary to interpose other positive conditioned stimuli, or, better, negative conditioned stimuli, which evoke the process of induction causing the opposite stimuli to act better. These interposed conditioned stimuli may be ones connected with the same unconditioned reflex.

CONDITIONED REFLEXES AND BEHAVIOUR

The behaviour of man can be viewed from the standpoint of Pavlov as a long chain of conditioned reflexes. In the laboratory we can form chains of only two or three conditioned reflexes in the dog—that is, where one signal

is not the immediate signal for the unconditioned stimulus but for another conditioned stimulus, and so on through the chain of conditioned stimuli till the unconditioned stimulus is reached. In the child, chains of much greater length have been elaborated. The child is more plastic than the dog, and in it conditioned reflexes are more readily and more easily lost. This is true for the food reflex, but there is doubtless a variation for the different unconditioned reflexes. The fund of unconditioned reflexes varies markedly in each animal, so that the results obtained by working with one unconditioned reflex may not be comparable in different species as a measure of intelligence, capability, etc. A child would hardly be expected to establish easily a positive conditioned food reflex to a worm, nor a fish as readily as a child an investigating reflex to a drawing on a piece of white paper.

Although Pavlov has opened up a vast untrodden territory for exploration by his method of conditioned reflexes, and though we may find it of great aid in the investigation of psycho-biologic fields, we must remember that much caution and perseverance and further study is necessary before we can use it with confidence in the general explanation of phycho-biologic reactions (behaviour). He says: "It would be the height of presumption to regard these first steps in elucidating the physiology of the cortex as solving the intricate problem of the higher psychic activity in man, when in fact at the present stage of our work no detailed application of its results to man is yet permissible."

